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PECAN SOILS OF THE GULF AND SOUTHEASTERN STATES AND MAINTENANCE OF THEIR FERTILITY

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INTRODUCTION

Pecan production is confined principally to the southern United States. Pecans are grown on two major groups of soils. One group comprises the upland soils and the other the valley-land or river-bottom soils (bottom-land soils on flood plains and terraces). The latter group supplies the natural habitat of the native seedling pecan. Ninety-nine percent or more of the many thousands of seedling pecans are growing on these stream-bottom soils. On the other hand, it is estimated that 90 percent or more of the vast acreage of improved varieties of pecans is located on upland soils. Furthermore, the seedlings are largely confined to the area between the Mississippi River and west-central Texas, while the improved varieties are distributed for the most part on the uplands in the area east of the Mississippi River and northeastward to Virginia. The number of trees of the improved varieties is being increased more rapidly in the West than in the East. This development is principally in the irrigated section or in well-watered river bottoms. In some localities many native seedling trees are being top-worked to improved varieties.

Although these two groups of soils include a wide variation of soil types and soil conditions, only the better-drained and more fertile soils within these groups are well adapted to pecan production. Climate and soil conditions are the principal factors that confine successful pecan production chiefly to the southern United States. In the semiarid Southwest, particularly in southern New Mexico, Arizona, and

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[1] The correlation of soil series with pecan development and the preparation of the soil map was the work of E. D. Fowler.

California, where soils and temperatures are favorable, pecans are grown in limited areas by supplying water through irrigation. In the northern United States there are vast areas where soils and rainfall are favorable for pecan production, but temperature is the factor that limits production at least until varieties are found that are adapted to the short season and low temperature during the growing season. Even within the area that is favorable for growing pecans, many factors may preclude profitable production under existing conditions. Nutritional deficiencies, poor soil drainage and aeration, low-yielding varieties, and injury from insects and diseases are factors that may cause low yields and pecans of poor quality, and may prevent profitable production on any soil. In most cases these limiting factors can be eliminated, but not always economically in view of the present prevailing prices of pecans.

The distribution and characteristics of the soils on which pecans are grown have been studied in considerable detail. This work has been done in the field by examining conditions in a large number of the principal commercial pecan orchards (*13*, *14*, *20*).[2]

Figure 1 shows the approximate boundary of the principal pecan-producing area of the United States with the exception of the irrigated orchards of the Southwest (*18*). It also shows the general distribution of the principal pecan-producing soils in this area that are known to be best adapted to pecan production. This soil map is based on the classification of Marbut (*24*). For a detailed description and exact location of soil types in a specific locality the county soil survey maps of the Bureau of Chemistry and Soils of the United States Department of Agriculture should be consulted. These soils are designated by symbols in the map legend which distinguish them from soils that, owing to certain unfavorable soil characteristics or to unfavorable environmental factors, are not adapted to pecan production. The soil boundaries around these desirable soils delineate the potential pecan-producing areas. Small tracts of land unsuitable for pecan production are included within the limits of these soil boundaries. Some of these tracts are on steep slopes; others consist of soil that has become seriously impaired or on which drainage is inadequate. Impairment may be due to excessive erosion or to extreme depletion of available plant-food material. But whatever the cause, it should be recognized that these tracts are present in all parts of the pecan-producing belt and that they are not suitable sites for commercial pecan orchards.

SOILS UTILIZED FOR PECAN GROWING

UPLAND PECAN SOILS

Pecans have been observed growing on 31 different upland soil series and on 24 different valley-land soil series. These soils represent by far the larger proportion not only of those soils upon which pecans are growing but also of those adapted to pecan production.

The distribution of pecan trees in the southeastern and south-central belt in 1930 is shown in figure 2.

Soils in the Southwest, including western Texas, New Mexico, Arizona, and California, which are being utilized for pecan production, are not included in this report.

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[2] Italic numbers in parentheses refer to Literature Cited, p. 22.

It is estimated that 95 percent of the pecan acreage on the upland oil series is located on 7 of the 31 series. These

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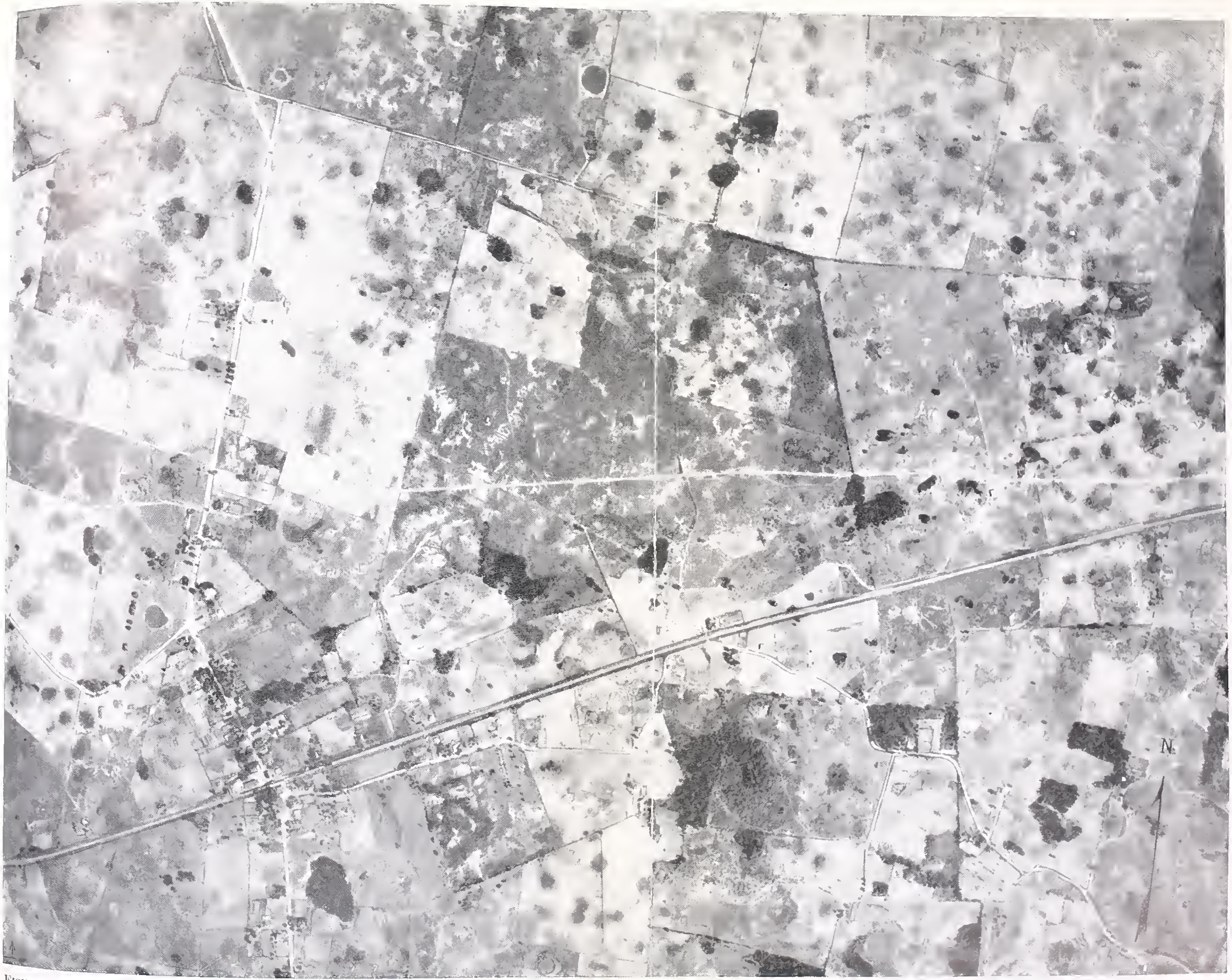

FIGURE 22.—Aerial photograph of a typical doline landscape near Rocky Hill, 5 miles southwest of Glasgow Junction. The area seen in this view has been inhabitated for a long time, and judging from the numerous gullies that appear on the short but steep slopes it has been cultivated with little regard to conservation of the soil.

California, where soils and temperatures are favorable, pecans are grown in limited areas by supplying water through irrigation. In the

It is estimated that 95 percent of the pecan acreage on the upland soil series is located on 7 of the 31 series. These seven are the Ruston, Norfolk, Tifton, Orangeburg, Greenville, Red Bay, and Cecil. These seven soil series have many common characteristics. They all occur on the higher and more level areas of the uplands where drainage is well established, both on the surface and through the soil to such depths that roots may grow well. The upper layers of these soil types are acid in reaction, except localized areas of the Greenville soil series. Their profiles are made up of three principal horizontal layers, varying in thickness. The first or surface soil layer is lighter in texture and color than the second or subsoil layer. This surface layer supplies most of the available plant-food materials for crops, and therefore the thicker and more fertile this layer, the better it is for pecan production. The principal differences between the upland and bottom soils with respect to their natural productiveness for pecans are due largely to the differences in depth of the surface soil layer, in the natural fertility of this layer, and in its capacity for holding water. This zone is normally 24 inches or less in thickness in the upland soils, averaging about 12 inches, whereas in the bottom soils it may be several feet in thickness, depending on the depth and character of the alluvial deposits forming it.

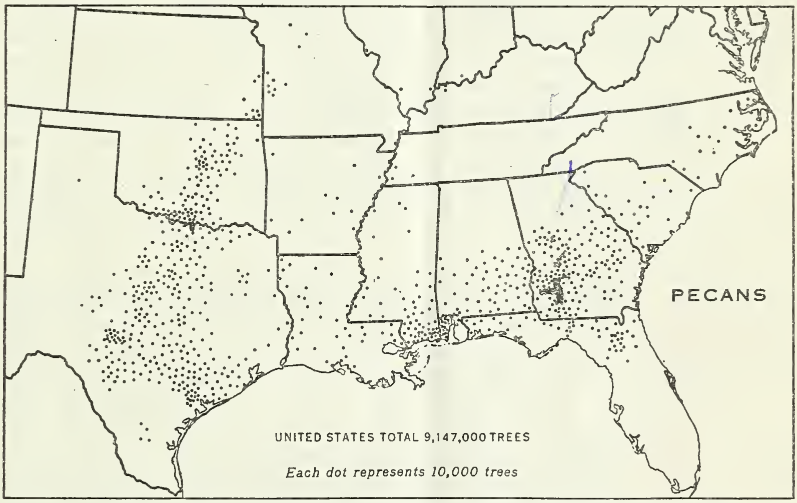
PECANS
UNITED STATES TOTAL 9,147,000 TREES
Each dot represents 10,000 trees

Figure 2.—Map of the southeastern and south-central pecan belt of the United States, showing the number of pecan trees in the different States in 1930. (From publication by Baker and Genung (*8*).)

In upland soils the surface layer is frequently deficient in nitrogen and organic matter and in many cases in available phosphate, potash, calcium, and magnesium, while the river-bottom soils are usually well supplied with organic matter and plant nutrients. The subsoil in all these seven series, though heavier than the surface-soil layer, is more or less friable and well aerated, since it lies above the permanent ground-water level; it is sufficiently heavy to retard leaching and hold moisture and is, as a rule, penetrated readily by the roots of trees and field crops. The surface soil is formed from this layer as the influence of soil-forming processes extends downward. The third principal layer is known as the parent material or substratum layer. It is as a rule somewhat lighter in texture than the subsoil but heavier than the surface soil. This is the material from which the subsoil is formed and it occurs in various stages of alteration from that which it originally had when deposited. The parent materials of some of these soils vary considerably owing to the difference in character of the rock from which they were formed. The Norfolk, Tifton, Ruston, Orangeburg, and Red Bay soils are derived from loose unconsolidated and unstratified materials ranging from fine sandy clays to coarse gravels in texture. The Greenville is developed from the weathered product of a siliceous limestone formation, and the Cecil from granites and gneisses.

The Norfolk and Ruston soils occur more extensively and are more widely distributed than other soils on which pecans are grown. They occur on both the Atlantic and Gulf Coastal Plains. The Norfolk occurs as far north as southern Virginia, and the Ruston extends into North Carolina. From these northern points they extend south and west into eastern Texas. In many places they are closely associated and grade gradually from one into the other. There are probably more pecans of the improved varieties growing on these two soils than on all other upland soils combined. They are not considered the best of the upland soils for pecan production, but they do respond well to soil-improvement practices and may be built up to a relatively fertile state.

The surface soils of the Norfolk and Ruston series are gray to light gray in color. This layer is 10 to 20 inches in thickness and consists chiefly of the mineral quartz. The texture of the surface varies from very fine sand to coarse sands. The sandy loams and fine sandy loams are the most desirable types for pecan orchards. The surface soil of the Ruston is commonly brownish yellow in the lower part, whereas the Norfolk is grayish yellow. Their subsoils differ in color. That of the Norfolk is yellow and that of the Ruston is brown to reddish brown. The subsoil varies from fine sandy clay to sandy clay, depending on the texture of the surface soil, and this in turn depends on the texture of the substratum or parent-material layer. These layers become quite firm and hard during dry seasons, but subsoiling operations are not considered necessary for orchard purposes on these soil types. Soil-improvement crops having roots that penetrate these layers will improve soil conditions for pecans more than mechanical subsoiling operations.

The substratum layers of the Norfolk and Ruston soils are almost identical in their range, color, and texture. This layer is characterized by an intricate mottling or network of streaks or seams of light gray, yellow, and red sandy clays. The gray material contains more clay and the red the least clay. This layer extends from an average depth of 5 or 6 feet at the upper boundary to many feet deep in places. The gray color, as a rule, becomes more pronounced with depth and represents the least altered parent material. The Norfolk soil in most cases occupies the more nearly level or flat areas, and the Ruston the adjoining slopes or breaks along streamways. An orchard-management program on these soils should include the addition of green-manure crops and commercial fertilizers.

The Tifton soils are rather limited in extent, occurring principally in southwestern Georgia, and also in scattered areas of southern Alabama, South Carolina, and northern Florida. This soil resembles the Norfolk soils in color, though as a rule the subsoil has a darker yellow color appearing greenish yellow in places. Also, both the soil and subsoil contain more fine silt and clay particles than the typical Norfolk subsoil. The occurrence of rounded iron oxide and sand-clay pebbles, forming 20 to 40 percent of the volume of the first two layers, distinguishes the Tifton most strikingly from the Norfolk soils. These pebbles range in size from small shotlike particles up to pebbles 1 inch or more in diameter. They impart to the soil a favorable mechanical condition. The Tifton soils are good farm lands; however, the total acreage devoted to pecans is relatively small. They are very good pecan soils in comparison with other upland soils of this territory.

The Orangeburg, Greenville, and Red Bay soils have some common characteristics. They are all derived from Coastal Plain deposits and have developed a characteristically red or brownish-red rather friable subsoil layer averaging rather heavy in texture. In places, particularly on the heavier types, it is advantageous to loosen up this heavy subsoil by growing subsoiling crops, such as kudzu. The subsoil of the Orangeburg series is much thicker than that of the other two soil series of this group. Both the Red Bay and Greenville soils have red-colored surface soils. The Red Bay soil is a lighter red and is sandier in texture. In contrast, the Orangeburg surface soil is gray or grayish brown in color. The parent material or substratum layer of the Orangeburg series is very similar in color, texture, and chemical composition to that of the Norfolk, Tifton, and Ruston soils. The parent material of the Red Bay is a quartz gravelly layer, and that of the Greenville a siliceous limestone formation known as Vicksburg limestone.

The Greenville soil is generally considered more fertile than the Orangeburg or Red Bay soils, and where a thick surface soil has developed it is one of the best of the upland soils for pecans. However, it is limited in extent and occurs chiefly in a rather narrow belt from South Carolina through southern Georgia, southeast Alabama, and northwest Florida. The Red Bay soils are more commonly found in parts of southwest Georgia and central and southern Alabama and Mississippi. Orangeburg soils are much more widely distributed, occurring over most of the territory in which the Ruston soils are found, but they are less extensive within this territory than the Ruston soils. The Orangeburg ranks next to the Greenville in suitableness for commercial production of pecans.

The Blakely, though a minor soil having only a small acreage of pecans growing on it, is worthy of mention here because it ranks first of the upland soils as a desirable pecan soil. It more nearly approaches the conditions of river-bottom soils than do other upland soils. The surface layer of the Blakely loam type is dark chocolate-brown and ranges up to 30 inches in thickness in places. This layer contains considerable organic matter, is relatively well supplied with most of the essential plant food elements, and retains moisture better than the average upland soil.

The Blakely soils have developed only in the region of the Greenville soils, with which they are very closely associated. They occupy well-drained shallow depressions or flats in the Greenville areas. The textures are predominantly loams or heavier types. The roots of pecan trees are naturally well distributed in a soil of this character, and fine feeding roots commonly extend to greater depths than in most upland soils.

The Cecil soils have gray to red surface soils and red, stiff, but brittle clay subsoils. However, throughout the profile they differ greatly in character and composition from the Orangeburg and associated soils. The Cecil soils are derived from the decomposition of granite and gneiss. They are generally considered to be the best of the piedmont soils. Drainage is adequate but not excessive. Much of the Cecil is developed on sloping land, and on the steep slopes erosion is severe unless proper control measures are used. Since pecans apparently require a certain amount of cultivation to reduce the competition with other plants, orchard sites should be selected that will permit cultivation without serious erosion. These soils occur in a belt lying immediately northwest of a line extending from Richmond, Va., southwest through Raleigh, N. C.; Columbia, S. C.; Macon and Columbus, Ga.; and ending near Montgomery, Ala. Only the southern portion of this belt is desirable for pecan production.

The remaining 23 soil series of the 31 different upland soils upon which pecans are grown are distributed over the whole pecan belt, but the total acreage of pecans on them is known to be relatively small. They are divided into three groups, consisting of well-drained, moderately drained, and poorly drained soils. The soil types of each group are described in table 1.

TABLE 1.—*Description of upland soils utilized for pecan growing*

WELL DRAINED

Soil series	Distribution	Surface soil	Subsoil	Substratum or parent material	Value for pecans
Carnegie	Coastal Plain, southwest Georgia.	Brown pebbly sandy loams and loams, nearly level.	Reddish-yellow sandy clays, friable.	Mottled reddish-brown, gray, and yellow sandy clays, friable.	Good.
Davidson	Piedmont Plateau of north Alabama, Georgia, South Carolina, and North Carolina.	Dark-reddish or chocolate-brown loams to clays, smooth slopes.	Dark reddish-brown clay, only moderately friable.	Ferromagnesium rocks of dense structure and dark colors. First product, heavy and sticky.	Fair.
Kirkland	Central Oklahoma, south-central Kansas, north-central Texas, Permian "Red Beds."	Brown to dark brown, gently rolling.	Brown to chocolate-brown, heavy clay.	Dark-red, partly weathered, calcareous shales, and some sandstones.	Poor.
Kirvin	Coastal Plain in east Texas, Louisiana, Mississippi, and Alabama.	Light-brown to reddish sandy loams chiefly, gently rolling.	Red with some gray mottlings, moderately friable sandy clays.	Mottled red, gray, and yellow clays or sandy clays.	Fair.
Marlboro	Atlantic Coastal Plain chiefly in North Carolina and South Carolina.	Gray sandy loams chiefly, gently rolling.	Deep-yellow sandy clay with some red mottlings in lower depths.	Mottled yellow, gray, and red sandy clays.	Good.
Windthorst	North-central Texas	Undulating, brown to reddish-brown sandy loams chiefly.	Red, heavy, and crumbly sandy clays.	Sandstone and beds of sands	Fair.

MODERATELY DRAINED

Soil series	Distribution	Surface soil	Subsoil	Substratum or parent material	Value for pecans
Acadia	Lower Coastal Plain of southeast Texas and southwest Louisiana.	Nearly flat, light brown or gray sandy loam to sandy clays.	Gray to gray-brown mottled rather heavy dense clay, acid.	Heavy clay, permeable and calcareous.	Fair on sandy types.
Appling	Piedmont Plateau in association with Cecil (timbered).	Nearly level, grayish to light-brown sandy loam.	Reddish-yellow or mottled light-red and yellow friable clay.	Partly disintegrated granites and gneisses.	Generally poor but fair in better-drained places.
Blanton	Southeastern lower Coastal Plain (timbered).	Nearly level, loose light-gray sands.	Pale-yellow to creamy-white sandy clays.	Mottled gray and yellow and brown sandy clays.	Fair.
Caddo	Upper Coastal Plain of Texas and Louisiana (timbered).	Nearly level, gray with yellow subsurface.	Yellow with gray mottlings in lower part, sandy clays.	Mottled gray and yellow sandy clay.	Poor.
Houston	Blackland prairies in Texas, Arkansas, Mississippi, and Alabama.	Undulating to rolling black and brown calcareous crumbly soils, mostly heavy and of clay texture.	Dark-gray or yellowish-brown calcareous friable clay.	Marl and chalks	Fair with sufficient moisture.
Lake Charles	Coast prairies of southwest Louisiana and southeast Texas.	Dark-brown to black undulating dark prairie soils.	Dark-gray to black heavy clay and acid to neutral.	Light-gray calcareous clays or marls.	Poor.
Leon	Lower Coastal Plain of Southeastern States (pine and palmetto).	Nearly flat, gray sandy surface, acid.	Coffee-brown iron oxide zone very acid and hard.	Mottled gray and yellow sandy clays, acid.	Do.

TABLE 1.—*Description of upland soils utilized for pecan growing*—Continued

MODERATELY DRAINED—Continued.

Soil series	Distribution	Surface soil	Subsoil	Substratum or parent material	Value for pecans
Nimrod	Residual sandstone blow sand of north central Texas, associated with Windthorst.	Nearly flat or depressed, gray acid sands.	Yellow acid sandy clay	Mottled sandy clays and sandstone.	Poor.
Oktibbeha	Marl and slightly calcareous clays, Texas, Mississippi, and Alabama.	Rolling, brown or reddish-brown sandy loams to clay.	Dark-red silty clay to clay mottled with yellow and red and gray.	Brownish-yellow to light-gray calcareous clays and marly limestone.	Fair.
Pheba	Upper Coastal Plain of Louisiana, Mississippi, and Arkansas (timbered).	Nearly flat, yellow sands to silts; acid. Loess influence.	Yellow sand clays mottled gray to reddish in lower part.	Mottled gray, yellow, and reddish sandy clays.	Fair on better-drained places.
Susquehanna	Coastal Plain from Carolinas to Texas (timbered).	Gray or brownish-gray sand or reddish clays; acid.	Second layer usually thin or missing. Is normally reddish brown; acid.	Mottled, acid, plastic red, yellow-gray, and purplish sandy clay to clays.	Poor in most places.
Tabor	Upper Coastal Plain of east Texas chiefly.	Undulating, gray sandy loams; acid.	Yellow sandy clay with faint red and gray mottles in lower part.	Mottled yellow, gray, and reddish acid sandy clays.	Fair.

POORLY DRAINED

Soil series	Distribution	Surface soil	Subsoil	Substratum or parent material	Value for pecans
Bladen	Lower Coastal Plain of Southeastern States.	Nearly flat, gray sandy loams; acid.	Gray or drab, heavy sandy clay with yellow or brown mottlings.	Gray to light-gray sandy clay with yellow mottles.	Poor in most places.
Grady	Residual from limestone occurring in limesinks on Coastal Plain.	Nearly flat or depressed, gray sandy loams to clay; neutral to acid.	Gray sandy loam clays with yellow and sometimes red mottlings.	Light-gray marly limestone with clay or sandy clay pockets; alkaline.	Poor, owing to root restriction.
Orelia	Plains of south and southwest Texas.	Flats and depressions. Dark-brown or black sandy clays and clay; acid.	Light and dense dark-brown and grayish clays, acid to neutral.	Grayish calcareous clays	Poor in most places.
Plummer	Middle and lower Coastal Plain of Southeastern States.	Flat or depressed acid gray sands and sandy loams.	Gray sandy clay with faint yellow mottlings; acid.	Mottled yellow and gray sandy clay; acid. Waterlogged usually.	Poor.
Victoria	Plains of south and southwest Texas.	Flat to undulating very dark-brown to black calcareous sandy clay and clay.	Dark-gray to brown or yellowish-brown calcareous clays.	Calcareous clays or marls	Do.

VALLEY-LAND PECAN SOILS INCLUDING THOSE ON FLOOD PLAINS AND TERRACES

Of the 24 valley-land soils discussed in this report there are 9 on which it is estimated that 80 percent or more of the seedling crops of pecans are produced. Previously, it has been stated that approximately 90 percent of the acreage of the improved varieties is on the upland soils. It is estimated that by far the larger portion of the remaining 10 percent is grown on these 9 bottom soils.

These soils consist of members of the Miller, Yahola, Sharkey, Sarpy, Trinity, Pledger, Catalpa, Cahaba, and Kalmia soil series. The first seven are first-bottom soils and the other two are terrace or second-bottom soils. These nine soil series are described briefly with particular reference to their distribution and occurrence, character of the material, and adaptability for pecan production so far as soil characteristics are concerned.

The Miller and Yahola soils are very closely associated in their occurrence along the major stream bottoms in central and eastern Texas, southern Oklahoma, Arkansas, and Louisiana. They are red soils composed of materials washed from the Permian "Red Beds" and other red-soil areas at the headwaters and along these streams. They are calcareous from the surface down, and both are red to chocolate red in color. They differ primarily in the character of the subsoil layers. Miller soils have subsoils of heavier texture than the immediate surface layers, whereas the Yahola subsoils are lighter in texture. Alternating sand and clay lenses or thin beds are commonly found. Both have sandy layers or deposits occurring in the substrata, thus making them well-aerated and rapidly drained of excess water following flooding. They receive additional deposits from overflows at times, and for that reason they are very fertile and available plant food material is found at considerable depths. Very large, heavily producing trees grow on these and other bottom soils. There is a larger acreage of improved varieties growing on these two soils than on any of the other first-bottom soils.

The Sharkey and Sarpy soils are also very closely associated in their occurrence, having a relationship to each other similar to that found in the Miller and Yahola soils. They are both first-bottom soils composed of alluvial material washed largely from the glacial regions of the Middle Western States. They are confined in distribution to the Mississippi River Valley and larger stream tributaries. The Sharkey soil is black to dark brownish in color. Dark-gray and drab-colored clays, sands, and silts continue down to many feet deep in places. Drainage is slow through much of the profile, and native seedling trees are found chiefly in the better drained areas of this type. The Sarpy soil is lighter in color and texture than the Sharkey. It has a dark-brown to brown surface soil ranging in texture from fine sandy loams to silty clays. The subsoils are brown to grayish brown in color, and sandy layers occur as lenses or cross-bedded layers in the subsoil. Sarpy is developed on the natural levees near the streams or channels, whereas the Sharkey occurs farther back from the main stream, as a rule, where backwater has deposited heavier materials. Both the Sharkey and Sarpy soils are well adapted to pecan production where sufficiently drained and protected from flood currents. Large native seedlings are commonly found on these soils, and the oldest planted pecan orchards known are growing on them. Overcrowding is quite evident in some of these old orchards. The largest and finest trees are in those places where they have had the least crowding from surrounding trees.

The Kalmia and Cahaba soils also are two very closely associated soils. They are developed on the better drained portions of second river bottoms along the larger streams of the Atlantic and Gulf Coastal Plain. Therefore they are very widely distributed, occurring from Chesapeake Bay through the Coastal Plain to central Texas.

The color profiles of the Kalmia and Cahaba soils correspond to those found in the Norfolk and Ruston, respectively; that is, they both have grayish-colored surface layers and mottled gray, yellow, and red substrata. But the subsoil of Kalmia is yellowish and that of the Cahaba brownish. They are inherently less fertile than the first-bottom soils previously described, and they are acid soils. However, like the Norfolk and Ruston, they are desirable agricultural soils and respond well to good management and are equally as well adapted to pecan production as the Norfolk and Ruston soils. They are not, however, a natural habitat for the native pecan. Very few, if any, pecan trees are growing on these soils except where they have been planted.

The Trinity and Pledger soils are first-bottom soils occurring along streams in eastern and central Texas chiefly. They are both calcareous and very deep fertile soils subject to annual overflow in most places. Their surface soils are black or very dark brownish gray. But the subsoil of the Pledger is red or chocolate red, and that of the Trinity is black or very dark gray. The Pledger is formed from materials washed from the black calcareous prairie region and from the region of red soils on the Plains. The Trinity soils are much more extensive than the Pledger. They are, as a rule, heavier and therefore not so well drained as the Pledger. Pecans grow well on the better-drained areas of both of these soils. In Wharton County, Tex., which is one of the largest pecan-producing districts, practically all the pecan trees are growing on the Trinity and Pledger soils; these soils occur in the first bottoms of the Colorado and San Bernard Rivers, which pass through this county.

Another bottom soil is the Catalpa. It has developed along a number of streams in central and eastern Texas, also in Alabama and Mississippi. Some are found in southern Oklahoma and Arkansas. Occasional overflows occur on part of this soil, but several seasons may pass without an overflow. The Catalpa soils occur on nearly flat first bottoms in Texas, Alabama, and Mississippi. They have brown surfaces and subsoils and are calcareous throughout their profile. Clays and clay loams are the principal types, but, even though they are predominantly heavy soils, drainage is free enough in many places for excellent pecan growth. They are rather limited in extent, but these soils form some of the most highly prized pecan land.

The description of the remaining 15 bottom soils of the 24 on which pecans are found growing most commonly is given in table 2.

TABLE 2.—*Description of valley-land soils, including those on flood plains and terraces, utilized for pecan growing*

Soil series	Distribution	Surface	Subsoil	Substratum or parent material	Value for pecans
Amite	Terraces of Coastal Plain streams from Virginia to Texas.	Nearly level. Red to reddish-brown acid silt loams to clay.	Red to bright-red friable sandy clay to silty clay.	Mottled red, yellow, and gray stratified sands and clays.	Good if well cared for.
Calhoun	Terraces of Arkansas and Mississippi River, chiefly in eastern Arkansas.	Light grayish-brown silts with nearly white subsurface; acid.	Gray to bluish-gray silty clays or clays mottled with yellow and brownish colors.	Beds of alluvial silts, clays, and sands.	Poor.
Frio	Terrace soil of central to south-central Texas. Subhumid region.	Nearly level dark-brown calcareous clay loams to clay.	Brown to dark-brown clays	Clays and gravels of stream deposits.	Good where water is available.
Guadalupe	First-bottom soils along Guadalupe River and other south Texas streams.	Grayish-brown river flood plain; calcareous.	Fine sand to clays quite variable and light brown to gray.	Calcareous heavy silty clays in many places.	Good in better-drained places.
Lintonia	Terrace soils from loess along Mississippi River bottoms in Arkansas, Louisiana, and Mississippi.	Flat to undulating light-brown silt loams.	Faint yellowish-brown or reddish-brown silty clay loams.	Water-laid silts and clays	Good.
Lonoke	Old high-bottom soils of Arkansas River bottoms.	Flat to undulating dark-brown sandy loams to clays; acid.	Purplish or pinkish-red sandy clays to clays mottled with gray; acid.	Calcareous purplish-red clays and sands.	Fair.
Monroe	Old first-bottom soils of Ouachita River in north Louisiana.	Nearly flat, gray silt loam to fine sandy loam; acid.	Mottled gray and brown silty and sandy layers.	Alternating layers of clays, silts, and sands; calcareous.	Good in better-drained places.
Ochlockonee	First-bottom soils along Coastal Plain streams from Texas to Virginia.	Stream flood plains of brown to grayish-brown sands to clays; acid.	Brown or yellow sandy clays or clays.	Mottled sandy or clayey alluvial deposits from acid Coastal Plain uplands.	Fair in best-drained places
Olivier	Old terraces of the Arkansas River.	Nearly flat grayish-brown silts and silty clays; acid.	Yellow upper subsoil grading to mottled yellow, gray, and brown compact clay.	Heavy silts and clays	Poor.
Osage	Alluvial first-bottom material, chiefly from sandstones and shales of Great Plains.	Nearly flat dark-brown to black silt loams to silty clay loams; acid to neutral.	Friable, heavy, gray or brown silty clay to clay.	Alluvial wash from sandstone, shale, and limestone soils of Great Plains.	Fair in best-drained places.
Portland	Old alluvial soil of Arkansas and Red River Valleys chiefly.	Nearly flat, brown to chocolate-brown silts and clays; acid to neutral.	Pinkish to reddish-brown clays, mottled and alkaline in places.	Purplish-red deposits from "Red Beds"; alkaline.	Poor except in better drained places.
Pulaski	Old high-bottom soil associated with Portland and Lonoke soils in Arkansas, Oklahoma, and Louisiana.	Nearly level, brown, rather well-drained silts and clays; acid.	Grayish-brown to mottled brown, yellow, and gray sandy clays.	Light-reddish or purplish-red sandy deposits; alkaline.	Good in better drained places.
Spur	Alluvial soils in valleys receiving wash from dark Great Plains soil.	Chocolate-brown silts to clays; alkaline.	Friable reddish-brown sands to clays.	Alluvial silts, clay, and sand deposits from dark Great Plains soil; calcareous.	Good where moisture is favorable.
Verdigris	Stream bottoms of northern Oklahoma and Kansas.	Dark-brown to almost black silt loams, loams, and silty clay loam.	Light-brown to light grayish brown silt loam, fine sandy loam or silty clay.	Light yellowish-brown to yellowish-gray fine sandy loam—some mica.	Good in better drained situations.
Waverly	Old alluvial deposits in poorly drained areas. Widely distributed over central to southern United States.	Flat to undulating gray to light gray silts and silty clays; acid.	Mottled gray, bluish gray, and yellow silty clay and clay.	Mottled gray and yellow alluvial sands and silts or clays from sandstone and shale soils.	Poor.

GREEN-MANURE CROPS FOR MAINTAINING FERTILITY IN PECAN SOILS

FOR UPLAND SOILS

Most of the upland soils used for pecans are good agricultural soils and with proper management support good growth and give profitable yields of general farm crops adapted to the region. Production may be most profitable when the soils are supplied with organic matter and liberal amounts of fertilizers are used. The productive capacity of the soil types vary, depending on many conditions, such as drainage, moisture-holding capacity, organic-matter content, crop practice, farm management, fertilizer treatment, etc. Their fertility may be maintained and improved by rotation of crops, growing and turning under of leguminous green-manure crops, and by the addition of manures, soil amendments, and commercial fertilizers.

Summer crops most commonly used in the pecan belt for green manure and soil improvement are velvetbeans, soybeans, cowpeas, clovers, sweetclover, crotalaria, kudzu, and lespedeza; and the winter crops are Austrian winter peas, vetches, and small grains. Many of the crops are adaptable to pecan orchards. However, where insects causing black pit or kernel spot of pecans occur, crops that are host plants, such as cowpeas and soybeans, should be avoided. The growing of legumes for turning under is one of the most economical means of maintaining soil fertility and crop production in pecan orchards. The most effective maintenance of soil fertility results only when the entire vegetative matter produced is allowed to decompose on the surface of the ground or when it is disked in the surface soil. Legumes grown and cut off do not generally enrich the soil with nitrogen and organic matter, for considerable plant food is removed by the crop. Soil organic matter and soil fertility can be most effectively maintained and improved by growing both a summer and winter green-manure crop. This practice, in addition to adding nitrogen and organic matter, prevents leaching and conserves the plant-food elements for tree consumption. The selection of the green-manure crop may best be determined by local conditions and by the crops best adapted to the orchard management. When the soil is very low in organic matter and the object is to supply this, the crop that will produce the most growth in the time available may be selected, whether a legume or a nonlegume, and therefore in improving poor or worn out soils, a nonlegume, such as rye or wheat, may serve better than legumes.

In an experiment in a pecan orchard on Norfolk sandy loam (*28*), where winter and summer crops were grown for 5 years and turned under for manure—the crops being cowpeas, velvetbeans, and beggarweed in the summer, and bur-clover, oats, and rye in the winter—the organic matter expressed as carbon was increased from 0.64 to 1.39 percent, more than doubled, and the nitrogen was similarly increased. As a result of the increased organic matter and nitrogen in the soil, the growth of the pecan trees improved and nut yield was markedly increased. On Bladen fine sandy loam, where a winter and summer cover crop was grown for green manure and turned under, the organic matter content of the soil was increased in 7 years from an equivalent of 0.50 to 1.42 percent of carbon. However, on a Norfolk sand under similar treatments it was difficult to maintain an organic-matter level of 0.55 percent of carbon over a 7-year period. More efficient soil building on this sandy type of soil has been accomplished by allowing the debris from green-manure crops to decay on the surface. When these crops are incorporated in such coarse-textured soil, decomposition under high temperature and favorable moisture conditions is very rapid, and the plant-food material resulting from the decay of the green manure quickly leaches from the soil.

Blackmon (*9*, *10*), of the Florida Agricultural Experiment Station, reports results of a green-manure experiment on Norfolk sandy loam made in north Florida in which he compared for 6 years Austrian Winter peas, hairy vetch, oats, and rye as winter green-manure crops for pecan orchards. Crotalaria was grown on all plots in the summer and the vegetation turned under. The trees made a more rapid growth where vetch and Austrian Winter peas were used as winter crops and gave larger yields of pecans than where no winter cover crop or nonlegumes were grown. The details of experiments in Florida showing the effect of various cover crops on soil improvement in pecan orchards have since been reported by Blackmon and Barnette (*11*). In an experiment on Norfolk sandy loam in Georgia various methods of handling cover crops were studied (*19*) and their effects in maintaining the soil's nitrogen and organic-matter level noted. The greatest increase was secured from Austrian Winter peas or vetch grown as winter cover crops and the plant residue disked in the soil, followed by a cover crop of velvetbeans. These treatments were superior to annual planting of crotalaria or Bermuda grass allowed to grow undisturbed.

Another illustration, which may serve to show the value of increasing organic matter in soils by growing green-manure crops, is an experiment on Orangeburg sandy loam in which kudzu was grown as a permanent cover crop on one plot and velvetbeans as a summer cover crop on another plot. In the case of kudzu the organic matter in the soil expressed as carbon was 1.00 percent after 1 year, 1.14 at the end of 2 years, and 1.25 percent at the end of 3 years. In the velvetbean plots the carbon was 0.90 percent after 1 year, 1.06 after 2 years, and 1.12 percent after 3 years. Tree condition improved and pecan-nut yield markedly increased.

Of interest in connection with maintaining organic matter and nitrogen in pecan soils is a green-manure experiment on Tifton sandy loam covering a period of 10 years, where Austrian Winter peas, vetch, and rye were used as winter cover crops and corn and cotton grown in rotation in the summer. The yields of field crops were increased by each green manure crop, but were greatest where vetch and Austrian Winter peas were used. The organic matter was maintained at a level somewhat greater than when no winter cover crop was grown; however, the soil nitrogen was maintained at about the same level, indicating that there was a rapid decomposition of the green-manure crop under this system of crop management. The decomposition of the organic matter into nitrogen forms available for plants was apparently rapid and possibly entirely utilized by the farm crop removed for sale. In another experiment (*1*), on a coarse-textured phase of Norfolk soil type, cowpeas, soybeans, and velvetbeans, as summer green-manure crops, and cowpeas as a summer crop with rye and vetch as a winter crop grown every third year in rotation with field crops of corn and cotton, did not increase or maintain the nitrogen or organic-matter content of the soil. The decomposition of the vegetative matter was very rapid, and available plant-food material apparently leached from the soil in a short period. In this experiment the summer and winter green-manure crops maintained the soil fertility at a higher level. On this soil the use of soluble commercial nitrogen in conjunction with green-manure crops maintained a lower carbon-nitrogen ratio in the soil, resulting in a higher level of soil fertility. These illustrations in the pecan belt, showing the relative efficiency of various crops and cropping systems in conserving soil nitrogen and organic matter, are a matter of considerable interest to pecan growers and all other types of farmers.

FOR VALLEY-LAND SOILS

Valley-land or river-bottom soils are naturally high in fertility as compared with upland soils. These soils vary in fertility, depending on the materials from which they are derived. The river-bottom soils derived in whole or in part from calcareous uplands are more fertile than those derived from sandy acid uplands. Regardless of the origin of river-bottom soils, the natural fertility is gradually depleted with continuous cropping and no renewal of fertility.

The same green-manure crops, discussed on pages 12–14, used to increase and maintain the fertility of upland soils, are equally effective on river-bottom soils. In an experiment on a Yahola soil in Louisiana the organic-matter content was increased from an equivalent of 0.9 to 1.6 percent of carbon (*7*) in a 3-year period by growing and turning under summer and winter cover crops.

In regions where summer rainfall is light, it is not advisable to grow a summer green-manure crop, as the growth of this crop may use moisture needed by the trees. On a Yahola soil (*25*) in northwest Louisiana over a 3-year period the growth of a summer green-manure crop apparently decreased the average yield 20 pounds of nuts per tree. In areas where cotton root rot is prevalent it is not advisable to grow legume crops, as they tend to increase the spread of root rot which attacks pecan trees, especially when they are young.

Pecan trees on Kalmia fine sand, a second river-bottom soil and acid in reaction, made more growth in an experiment in Georgia (*29*) when a winter cover crop of grain and a summer legume crop were grown and turned under as green manure than when native grasses were grown in summer and allowed to remain fallow in winter.

FERTILIZERS FOR GREEN-MANURE CROPS

In the growing of cover or green-manure crops for soil improvement in pecan orchards best results may be secured on most soils if small quantities of fertilizer are used when the seed is planted. On many soils cover crops do not thrive unless fertilized. In an experiment in Alabama (*31*) the vegetation of a cover crop of vetch, planted for soil improvement, was increased approximately four times by the use of 400 pounds per acre of superphosphate. Superphosphate used at the rate of 240 pounds with 50 pounds of potassium chloride gave a larger increase in vegetation and resulted in larger returns from the succeeding crop. In experiments in Florida (*32*) vetch and Austrian Winter peas on soils better than the average produced most vegetation on land that received superphosphate. From the results of experiments on a large group of soils devoted to the growing of pecans (*11*) it was concluded the best practice was to apply, before or at time of planting the winter cover crop, 300 pounds per acre of superphosphate and 60 pounds of potassium sulphate or potassium chloride. Frequently it is advantageous to apply, in addition to phosphate and potash, a small quantity of soluble nitrogen in late winter or early spring, which should stimulate the growth of cover crops.

By increasing the growth and vegetation of cover crops in pecan orchards by the use of fertilizers, the soil fertility can be maintained at a higher level without additional cost of fertilizing the orchard, for the amount of fertilizer applied to the trees in the spring can be reduced.

A discussion of the fertilizer requirements for various soils for pecan production is given on pages 15–17. When cover crops are grown for soil improvement, practices should be followed that will result in the production of the most vegetation. Phosphate or phosphate and potash can be advantageously applied when the winter or summer cover crop is planted, and the nitrogen can be applied to the pecan trees in early spring.

COMMERCIAL FERTILIZERS FOR MAINTAINING FERTILITY IN PECAN SOILS

The application of commercial fertilizers to the soil, the addition of organic matter, the growing of cover crops to maintain and increase the organic matter of the soil, and the practice of proper cultural methods constitute some of the principal means by which growers can maintain the productivity of pecan soils. In the foregoing discussion the influence of commercial fertilizers in maintaining successful pecan orchards on soil of different types and orchards under different cultural management has been pointed out. Many inquiries are directed to the Department concerning the fertilizer materials best suited for pecans, the advantage of using mixed fertilizers, the best fertilizer formula and analysis, sources of fertilizer materials, time of application, quantities to apply, and methods of application of fertilizers in pecan orchards. These questions are discussed in the following sections.

FOR UPLAND SOILS

The upland soils of the Pecan Belt are generally low in plant-food elements, and the yields of crops may be increased by the addition of commercial fertilizers. Fertilizers are most effective in pecan orchards when the organic matter of the soil is maintained at a high level. In the growing of general farm crops, such as cotton, which is universally grown in the greater part of the Pecan Belt, all three major elements of soil fertility, nitrogen, phosphate, and potash, are required for most profitable yields. On many of these soils these fertilizer constituents are most efficient when used in about equal proportions. Nitrogen is deficient in most of these soils, and the greatest crop response is from this element; however, some of the soils, especially the Tifton and Ruston series, are deficient in potash, as determined by crop response.

Commercial fertilizers increase pecan tree growth and yields of nuts on most of the upland soils used for pecan growing. Fertilizers containing nitrogen, phosphate, and potash, in about a 1–2–1 ratio, have been satisfactorily used on many upland pecan soils, and they are generally applied in late winter or early spring. In some cases, it may be more practical to apply the fertilizer constituents separately. The phosphate, or phosphate and potash, can be applied to advantage when the cover crop is planted in fall or spring, and the nitrogen applied to the pecan trees in early spring.

There are variations in the ratios of nitrogen, phosphate, and potash, which may give best results with different soil types, as well as under different orchard and cover-crop practices. On most of the upland soils pecans show greatest response from nitrogen, while on others greatest response may be from potash. On Coxville fine sand in Florida (*12*) highest returns were obtained in an experiment with pecans in which a number of fertilizer analyses were compared, from fertilizers having 4 percent of nitrogen, 6 to 8 of phosphoric acid, and 4 to 6 of potash; while on Norfolk sandy loam, a soil closely related to the Coxville, best results were obtained from a mixture containing 6 percent of nitrogen, 8 of phosphoric acid, and 4 to 6 of potash. Nitrogen, phosphate, and potash used singly did not increase tree growth or yields of pecans as much as the composite fertilizers.

Other experiments on Norfolk sandy loam in both the eastern and central pecan belt have indicated a need for nitrogen as well as other fertilizer elements. Nitrogen alone, or fertilizers having a ratio of 6 to 9 percent of nitrogen in mixtures with relatively small ratios of phosphoric acid and potash, have proved effective in increasing pecan tree growth and yield. Potash, combined with nitrogen, has given best results. Potash deficiency on this Norfolk sandy loam has been shown by crop symptoms when potash was omitted over a period of years. For instance, cotton grown without the addition of potash may develop a bronzed foliage, which is shed early, and may produce small immature bolls, which do not open normally.

In experiments on Bladen fine sandy loam (*21*), where varying ratios of nitrogen, phosphoric acid, and potash were used, the mixture high in nitrogen with relatively low proportions of phosphoric acid and potash was most effective on tree growth and yield. On Blanton fine sand (*21*) results of experiments indicate that all three elements are essential for best pecan tree growth and that nitrogen and potash affect growth to a greater extent than phosphoric acid. The indications are that potash is much more important for pecan tree growth and yield on this soil type than on the average upland soils. The largest yields in the experiments made resulted from the 3–3–9[3] fertilizer ratio.

The Orangeburg and Greenville soils when well tilled and supplied with organic matter are naturally productive; nevertheless, pecan trees on these soil types respond to commercial fertilizers, as shown by more rapid tree growth and larger yields (*26*). It has been noted that most response is obtained from applications of nitrogen alone or complete fertilizers high in nitrogen. The fertilizer may be applied as a mixture to the pecan orchard, or the phosphate, or phosphate and potash, may be applied when green-manure crops are sown, and the nitrogen in early spring before the trees bud out. In an experiment on Greenville sandy loam (*18*), covering a period of 10 years, three quantities of nitrogen, with a constant amount of phosphate, 8 percent, and potash, 3 percent, were used in which 5 and 8 percent of nitrogen in the mixture produced more tree growth and larger pecan yields than did fertilizers containing 3 percent of nitrogen. The fertilizer containing 8 percent of nitrogen produced greater tree growth and larger yields of nuts on this soil than did the one containing 5 percent, indicating the need of nitrogen for pecans on this soil.

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[3] Fertilizer constituents in this circular are stated in the order N–P_2O_5–K_2O.

FOR VALLEY-LAND SOILS

As previously stated (p. 1), the valley-land or river-bottom soils are the natural habitat of the pecan. On these soils are found large old native trees that have yields recorded of over 1,000 pounds each (*30*). These large native trees have attained their size and high yields on deep well-drained soils with a moderate to plentiful supply of plant nutrients.

In northwest Louisiana, pecan trees on river-bottom soils have generally yielded considerably higher than similar trees of the same age on upland soils. Records over a 5-year period of well-developed and productive pecan orchards of the same variety and similarly fertilized show a yield on the river-bottom Yahola loam almost three times as great as on upland Orangeburg sandy loam. The large difference in favor of the river-bottom soil was due probably in most part to its greater usable water-holding capacity.

While the river-bottom soils are naturally fertile, commercial fertilizers have increased yields in experiments on these soils. In an experiment on Monroe silty clay loam in Louisiana when nitrogen alone and complete fertilizers containing nitrogen, phosphate, and potash were used, the former gave the highest yields and produced significant increases over no fertilizer and the complete fertilizers used. Sodium nitrate and ammonium sulphate gave equally high yields on Yahola loam. Larger yields were also obtained from nitrogen alone than from complete fertilizers. In these experiments green-manure crops were not grown, and very little cultivation was practiced.

On Lintonia silt loam and Yahola loam where winter green-manure crops were turned under regularly and clean cultivation was practiced in the summer, there was response from fertilizers. Mixtures containing nitrogen and phosphate gave higher yields than nitrogen alone or complete fertilizers.

In a fertilizer-ratio experiment in Georgia on Cahaba fine sandy loam, a second river-bottom or terrace soil used to a limited extent for pecan growing in the eastern belt and occurring widely in the south-central and western belt, a 3–3–12 fertilizer gave best results when compared with a 3–12–3 and 12–3–3, and nitrogen alone equivalent to the amount applied in the 12–3–3. This soil is acid; it is generally deficient in potash, as indicated by field crop response.

In experiments on Kalmia fine sand (*29*) in Georgia over a 4-year period, where complete fertilizer was first applied the third year after the orchard was planted at the rate of 3 pounds per tree, followed by applications for following years of 5, 10, and 15 pounds, a 4–8–4 fertilizer resulted in a gain in the circumference of the tree trunk of about 58 percent, whereas an 8-percent nitrogen mixture gave an increase of about 62 percent over no fertilizer.

SOURCES OF PHOSPHATE AND POTASH

In preparing a fertilizer mixture for pecans or in selecting a fertilizer material for application, consideration should be given to the materials containing the element. Superphosphate is the principal source of phosphoric acid in commercial fertilizers and is the most widely used source of phosphorus. Several grades are manufactured, ranging in phosphoric acid content from about 16 to 48 percent. Ground rock phosphate and basic slags may be used as separate applications to pecan trees or to cover crops at time of planting, but these are not used in commercial mixed fertilizers with nitrogen and potash. The effectiveness of ground rock phosphate may depend on its fineness and on the incorporation of green manure in the soil. Its availability is not as quick as superphosphate. Basic slags, if used year after year, tend to produce alkalinity that may be objectionable to pecans on some soils, especially those having a neutral or alkaline reaction.

The potash sources do not seem to differ widely in their effects. The sulphate of potash, muriate of potash, and potassium-magnesium sulphate are most widely used. The source may be chosen largely on the basis of the cost of potash content. In experiments on Greenville, Orangeburg, and Norfolk soils in Florida (*12*), there was not a wide difference in yield between the sulphate and muriate of potash. Possibly some pecan soils may be deficient in sulphur and in such cases potassium sulphate may be preferable.

SOURCES OF NITROGEN

The principal sources of nitrogen used in commercial fertilizers or applied singly for pecans are sodium nitrate, ammonium sulphate, urea, cyanamide, and natural organics, such as cottonseed meal, tankage, etc. The supply of natural organics available for fertilizers is gradually diminishing, these being replaced in part by byproduct ammonia or nitrogen of synthetic origin. Much of the commercial fertilizer on the market may derive its nitrogen principally or in part from anhydrous ammonia combined with superphosphate and from synthetic nitrogen, such as urea. In these mixtures dolomitic limestone may be advantageously included to offset the acid-forming characteristics of the mixture. Only relatively small quantities of cyanamide may be used in commercial fertilizers. This nitrogen source is used principally as a separate application in pecan orchards and should be applied in the fall or winter.

In selecting a nitrogen fertilizer for pecan soils its effect on tree growth and its residual effect on the soil should be given consideration. Some of the nitrogen fertilizers, such as sodium nitrate and cyanamide, tend to make the soil basic or alkaline, and others, such as ammonium sulphate and urea, tend to make it acid. Some are quickly available, such as sodium nitrate, ammonium sulphate, and urea; and others, such as the natural organics and cyanamide, are more slowly available. Trade conditions may cause fluctuations in the relative cost of the materials, and the sources that can be most economically purchased are likely to be in most demand. Fertilizers, having nitrogen from ammonia salts or urea, are acid forming but are used with good results if dolomitic limestone is included in the mixture. For most soils it may be best to use a mixture of nitrogen sources, some of quick availability, some of slow availability, and some having base-forming qualitites, together with those having acid-forming qualities A mixture with phosphate and potash found to have good effects is one having about equal proportions of sodium nitrate, ammonium sulphate, and cottonseed meal, as nitrogen sources In an experiment on Greenville sandy loam (*23*) various sources of nitrogen in fertilizers with phosphate and potash were used for 3 years Where the nitrogen was derived one-third each from sodium nitrate, ammonium sulphate, and cottonseed meal, as compared with a fertilizer having a single source of nitrogen, including sodium nitrate, ammonium sulphate, cottonseed meal, urea, and other synthetic nitrogen salts, tree growth was greater, and there was a larger and more uniform supply of soil nitrates available to the trees throughout most of the year.

It has also been shown that nitrogen sources markedly influence the reaction of pecan soils. In an experiment on Greenville sandy loam (*22*) having an original pH value of 5.42, urea in 3 years reduced the pH value of the soil to 4.99, ammonium phosphate to 4.76, ammonium sulphate to 4.65, cottonseed meal to 5.17, all making the soil more acid. Sodium nitrate raised the pH value of the soil to 5.72, calcium nitrate to 5.91, and cyanamide to 7.13, rendering the soil less acid or even basic in the case of the cyanamide, a pH value of 7.0 being considered as neutral. On alluvial soil in Louisiana (*2*) having a pH value of 6.05, sodium nitrate used in a complete fertilizer raised the pH value to 6.45 after 3 years and cyanamide raised it to 6.30, thus rendering the soil less acid; ammonium sulphate reduced the pH value to 5.05, thus making the soil more acid. On Orangeburg fine sandy loam (*2*) having a pH value of 6.10, cyanamide used in single, double, and triple quantities in 3 years raised the pH value to 6.30, 7.05, and 7.80, respectively; sodium nitrate to 6.50, 6.30, and 7.20, respectively; and ammonium sulphate lowered the pH value to 5.44, 5.05, and 5.11, respectively.

Most of the upland pecan soils are acid except where they have been formed under unusual conditions. A slightly acid reaction in the upland pecan soils is considered favorable for pecan development; however, high soil acidity may be unfavorable and retard the growth of pecans as well as render the growing of green-manure crops difficult. Soil-acidity studies of some eastern upland pecan soils (*28*) showed a range in pH value of 4.2 to 6.8, with most of the better soils examined ranging between 5.4 and 6.4. Some of the rich river-bottom pecan soils of the western belt have a pH value of 7.0 or above (*2*). Where pecan rosette, a nutritional disease, caused generally by a deficiency of zinc in the soil (*4*, *5*, *6*, *15*, *16*, *17*), occurs, the trees may not respond to the usual commercial fertilizers. For profitable use of commercial fertilizers the trees must first be freed of rosette; this may be accomplished on acid soils by the application of zinc suphate to the soil. On basic or alkaline soils, on which are many of the pecan groves in Texas and the Southwest, soil applications may not be effective in controlling the disease. In such cases, it is more advantageous to spray the trees with solutions of zinc sulphate. Zinc in alkaline soils is apparently combined with the other chemical constituents in an unavailable form (*3*), and when applications are made to the soil the added zinc may also be fixed in a short time so that it is not available to pecan trees. Details of soil and tree treatment for control of pecan rosette are given in the papers cited and in a mimeographed circular issued by the Department of Agriculture.[4]

PREPARATION OF FERTILIZER MIXTURES

As discussed in the preceding pages (pp. 15–17), many pecan soils are in need of a well-balanced fertilizer, although some orchards respond only to nitrogen, or nitrogen and phosphate, or nitrogen and potash, and when this is known the application of only the materials indicated should be most profitable. For general soil and orchard conditions, complete fertilizers of the approximate analyses and composition given in table 3 may be used.

TABLE 3.—*Approximate analyses and composition of a complete fertilizer*

Fertilizer material	Fertilizer analyses	
	4–8–4	6–8–4
	Pounds	*Pounds*
Superphosphate (18 percent P_2O_5)	889	851
Treble superphosphate (44 percent P_2O_5)		14
Sodium nitrate (16.2 percent N)	164	247
Ammonium sulphate (20.5 percent N)	133	195
Cottonseed meal (7.5 percent N)	355	533
Potassium chloride (50 percent K_2O)	160	160
Inert material	299	
Total	2,000	2,000

These mixtures have the nitrogen derived one-third each from sodium nitrate, ammonium sulphate, and cottonseed meal, and have the advantage over a fertilizer having a single source of nitrogen in that the nitrogen is gradually available and its availability should extend over a longer period. Sodium nitrate is quickly available, ammonium sulphate somewhat slower, and cottonseed meal very slowly available. Other natural organic sources, such as castor pomace meal, tankage, fish scrap, etc., have somewhat the same availability as cottonseed meal and could be substituted for it. Other sources of potash, such as potassium sulphate, can be used. These mixtures are more expensive than mixtures of similar analysis with nitrogen derived from sodium nitrate, ammonium sulphate, anhydrous ammonia, or synthetic nitrogen, such as urea. However, these nitrogen sources, except sodium nitrate, tend to produce acidity in the soil. This can be corrected by including dolomitic limestone in the mixture, and when this is done this grade of fertilizer gives good results. A fertilizer composed of these materials is suitable for pecan soils, except coarse sandy soils subject to excessive leaching. A 4–8–4 or 6–8–4 analysis can be made from some of these materials by the formula given in table 4.

If it is desired to use a more concentrated mixture than a 4–8–4 or 6–8–4, the ratios of fertilizer constituents should be approximately maintained. By the use of treble superphosphate, which contains about 44 percent of phosphoric acid; or ammonium phosphate, which contains about 48 percent of phosphoric acid and about 10 of nitrogen; or urea, which contains about 45 percent of nitrogen, a fertilizer high in the major plant-food constituents can be prepared.

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[4] UNITED STATES BUREAU OF PLANT INDUSTRY. PECAN ROSETTE AND ITS CONTROL. 4 pp. [Mimeographed.]

TABLE 4.—*Composition and analyses of fertilizer mixtures suitable for pecan soils not subject to excessive leaching*

Fertilizer material	Fertilizer analyses	
	4-8-4	6-8-4
	Pounds	*Pounds*
Superphosphate (18 percent P_2O_5)	889	448
Treble superphosphate (44 percent P_2O_5)	--------	181
Ammonium sulphate (20.5 percent N)	390	585
Potassium chloride (50 percent K_2O)	160	160
Dolomitic limestone	417	626
Inert material	144	--------
Total	2,000	2,000

TIME OF APPLICATION OF FERTILIZERS

The time of application of fertilizer in pecan orchards should vary according to source of materials, climatic conditions, and general orchard practice. Commercial fertilizers are generally applied in late winter or early spring shortly before or about the time the trees bud out. When it is desired to apply phosphate, or phosphate and potash, at the time of planting soil-improvement crops, this may be done when either the winter or summer crop is planted. When this practice is followed, nitrogen can be applied near the trees in early spring. Nitrogen in cyanamide becomes available slowly and requires plenty of moisture, and therefore when this is relied on as a source of nitrogen it should be applied in January or February. Sodium nitrate is quickly available, and ammonium sulphate moderately so, and if supplied too early may be lost in part, particularly if continued heavy rains should follow their application.

It may be noted that experimental evidence thus far shows that plant-food materials are most efficiently assimilated during the period of rapid growth in early spring, when about 80 percent of terminal growth normally occurs. Late-spring or summer applications have not given as satisfactory results and should not be relied on to furnish the main supply of plant-food material to pecan trees. A second or lighter application in May or June has increased yields on deep sandy soils and in orchards where grass, weeds, and other plants were successfully competing with the trees for the plant food elements. In a source-of-nitrogen experiment where a number of different materials were used in an otherwise uniform fertilizer, the distribution of nitrates in the soil varied somewhat. A mixture containing several sources of nitrogen, some quickly and some slowly available, supplied the most uniform distribution of soil nitrates, and it would seem such a mixture could be advantageously applied in very early spring. Where such material as ground rock phosphate is used it may be best applied in the fall.

QUANTITIES OF FERTILIZERS

The amount of fertilizers to apply in pecan orchards should vary with conditions. Young pecan trees should receive from 1 to 2 pounds of commercial fertilizer per tree for the first and second year after planting. The amounts applied should increase as the orchard becomes older. Many growers apply from 8 to 10 pounds per tree to 5-year-old trees. For orchards 10 to 12 years old the amount varies from 40 to 50 pounds per tree or from 600 to 800 pounds per acre. An average application is about 2.5 pounds for each year of the growth of the tree. From 1,000 to 1,500 pounds per acre have been used in well-developed orchards, but such large applications would probably be profitable only under special soil and climatic conditions. In an experiment with varying quantities of fertilizers in which as much as 200 pounds per tree was used, the results do not justify the heavier applications. In applications of nitrogen alone the concentration of the material used should be the guide. Rosetted trees or trees in very poor condition do not respond to large applications of standard fertilizer.

METHODS OF FERTILIZER APPLICATION

Methods of fertilizer application must vary, too. In large orchards mechanical distribution may be most economical, but hand applications may be made when they are more advantageous. On slopes the fertilizer must be held by barriers, holes, or sod, in order to prevent loss from washing. Under all conditions the primary object should be to distribute the plant-food material within reach of as many feeding roots as possible, keeping in mind that these feeding roots may penetrate any part of the surface-soil area from a point near the trunk to a distance approximately 2.4 times the spread of the limbs (*27*). Any method that will give effectively and economically a uniform distribution of fertilizer in this area of surface soil is considered desirable. Too often the fertilizer covers only a small part of the area occupied by the root system and is unevenly distributed in piles on top of the ground. Where practical, without loss of cover crop or increase in erosion, fertilizer should be worked into the surface soil. Particularly is this true of phosphates, for these move very little either vertically or laterally unless carried mechanically. Soil nitrate and potassium move more freely than phosphates through normally well-drained upland soils.

Broadcasting fertilizer over the entire soil area is desirable in old well-developed orchards. In young orchards it may be more advantageous to apply the fertilizer in a wide band under the tree, extending from a few feet from the tree trunk to the outer edge of the spread of the limbs.

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